Effect of non-ideal contacts in capacitance spectroscopy of $Cu(In,Ga)Se_2$ solar cells

J. Lauwaert, L. Van Puyvelde and H. Vrielinck
Department of Solid State Sciences, Ghent University, Krijgslaan 281-S1, 9000 Gent, Belgium

S. Khelifi and M. Burgelman
Department of Electronic and Information Systems (ELIS), Ghent University, St.-Pietersnieuwstraat 41, B-9000 Gent, Belgium

Thin film solar cells consist of several layers, like in the typical ZnO/CdS/CIGS/Mo architecture. Each deposition process influences the previous layers. Hence, the final device is the most appropriate for assessing the effect of defects in the absorber, e.g. using electrical characterization with capacitance spectroscopy. Such characterization techniques measure the response of the whole structure after applying a time dependent potential over it. This can be measured statically (current-voltage), dynamically (capacitance-voltage), and via admittance spectroscopy (AS) or Deep-Level Transient Spectroscopy (DLTS) recording a current or capacitance transient after a pulse. The first main challenge is to explain the observed signals. Afterwards one may use these explanations to improve the solar cell efficiency.

Although recently in CIGS technology efficiencies have been achieved beyond 20% on glass substrates [1] and exceeding 17% on a flexible polymer substrates [2], a lot of questions remain unanswered regarding the fundamental signals experimentalists observe for them. Among those are the frequently observed anomalies in fundamental parameters as open circuit voltage, short circuit current and fill factor, as listed in reference [3].

In this work we focus on the properties of the DLTS signals observed for CIGS solar cells, as typically measured on cells produced by EMPA (ETH Zürich, Switzerland). At low temperature a signal labeled N1 is usually observed, whose appearance seems independent of the manufacturing technology. A second peak appears at higher temperatures and gives rise to slow capacitance transients near room temperature. Following ref. 3, we label this signal N2. We demonstrate that both N1 and N2 exhibit the typical features of a non-ohmic contact [4]. Based on these findings we introduce the idea of modeling all interfaces in a structure as rectifying barriers, connected in series with one another. We show that such an electric circuit is able to mimic the typical DLTS and AS spectroscopy of a CIGS solar cell. The CIGS DLTS spectra are furthermore compared with those of other thin film solar cells, e.g. CdTe/CdS and P3HT-PCBM organic solar cells and with other layered electronic devices (Al-Ge-Au structures). It is remarkable that such structures all exhibit signals with similar properties as the fundamental signals N1 and N2, confirming their origin as additional barriers. Although DLTS and AS spectroscopy were originally invented to measure charging and decharging of defects, the main features observed in thin film solar cells all appear to be related with non-Ohmic contacts in the structure.

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